



# **Landsat 8 Geometric Performance**

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# Overview

## ◆ Geometric Performance

- Instrument fields of view and co-alignment
- Band registration accuracy
- Geodetic accuracy (without ground control)
- Geometric accuracy (fit to GLS control)
- OLI spatial performance
- On-orbit jitter assessment
- Geometric performance summary

## ◆ On-orbit Calibration Updates

## ◆ GLS Ground Control Accuracy

- Identification and repair of problem areas

## ◆ Ongoing Work

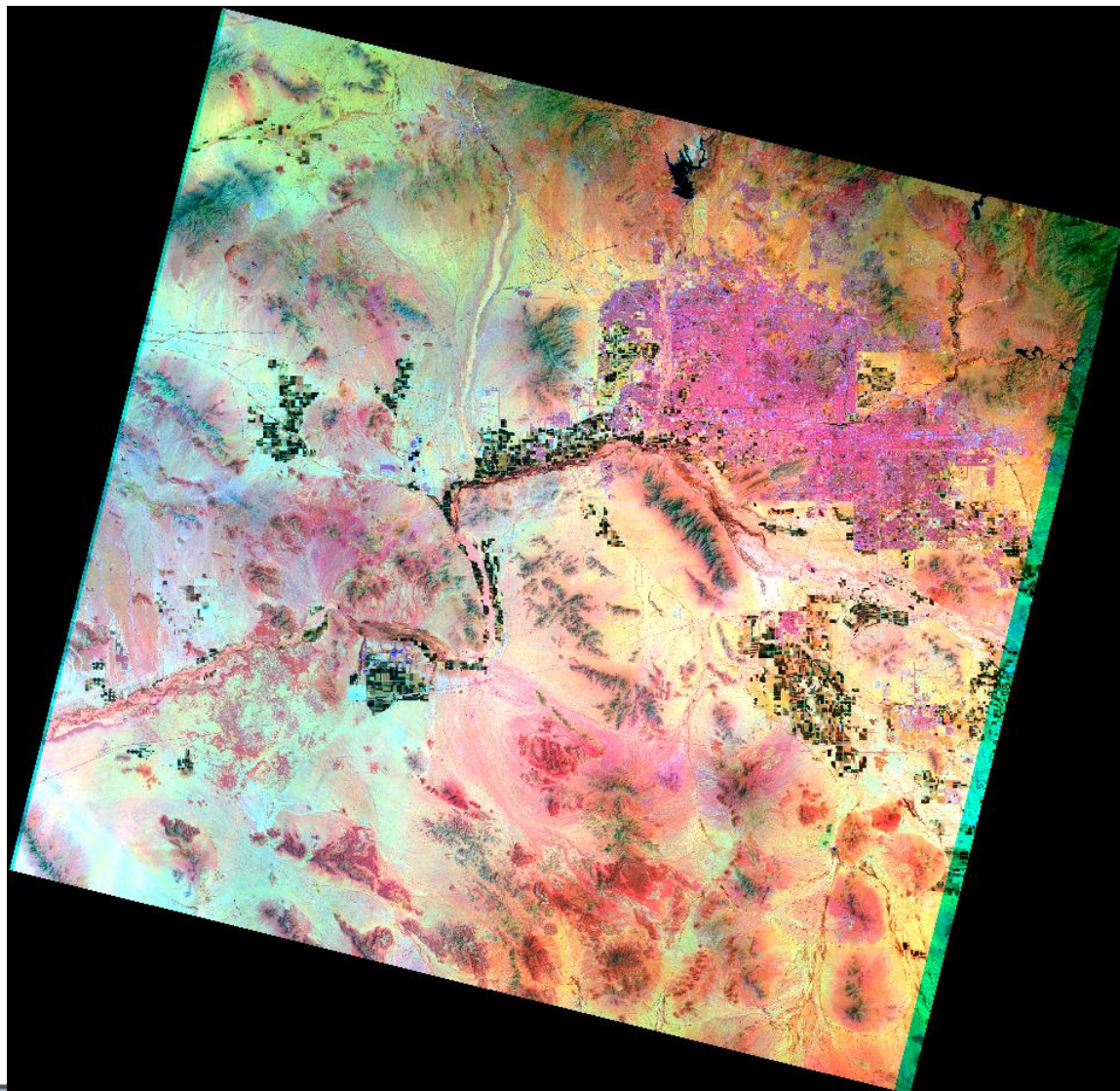
# TIRS-OLI Co-Alignment and Swath

- ◆ **Coincident OLI and TIRS imagery demonstrates that the TIRS field of view is completely contained within the OLI field of view**
  - The TIRS FOV is more closely aligned (~700 meters) with the western (starboard side) edge of the OLI FOV
  - The OLI FOV extends ~3.3 km beyond the TIRS FOV on the eastern edge
- ◆ **Swath width measured at row 060 (equator):**
  - OLI: 190.2 km vs. 185 km requirement
  - TIRS: 186.2 km vs. 185 km requirement
- ◆ **As a consequence of yaw steering, the L8 scenes are more rectangular (less Earth rotation skew) than heritage Landsat scenes**

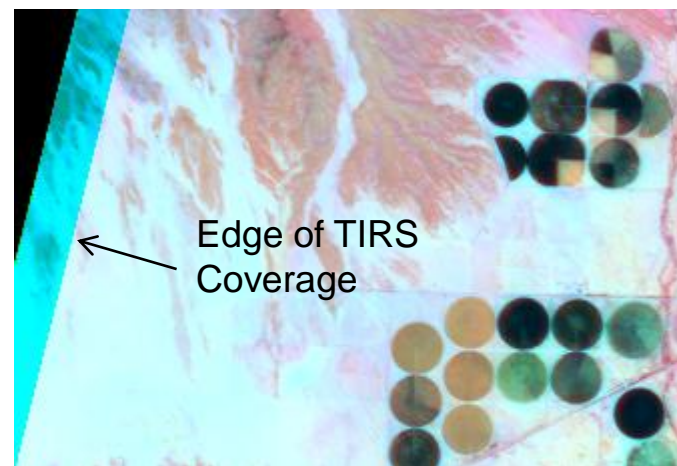


# Full Scene Coverage for 037/037

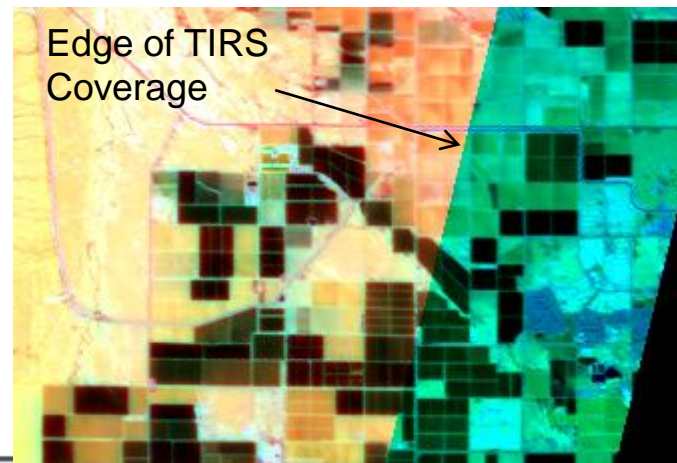
♦ Red = Band 10 (TIRS) : Green = Band 7 (OLI) : Blue = Band 1 (OLI)



West Edge of Scene



East Edge of Scene



# OLI Band Registration Accuracy

- ◆ **Band registration accuracy was evaluated using cloud-free scenes of selected test sites**
  - Mainly desert sites are used
  - Data acquired between April 15, 2013 and October 18, 2013 (operational WRS-2 orbit)
- ◆ **Results from 293 OLI registration test scenes:**
  - 12 high-altitude Earth scenes were used for cirrus band registration assessment
  - OLI band registration accuracy (worst band pair)
    - ❖ Line Direction: 3.97 meters LE90 (with cirrus)
    - ❖ Sample Direction: 4.07 meters LE90 (with cirrus)
    - ❖ Line Direction: 3.28 meters LE90 (no cirrus)
    - ❖ Sample Direction: 3.37 meters LE90 (no cirrus)
    - ❖ Specification: 4.50 meters LE90



# TIRS Band Registration Accuracy

## ◆ TIRS 10.8 $\mu\text{m}$ to 12.0 $\mu\text{m}$ band registration

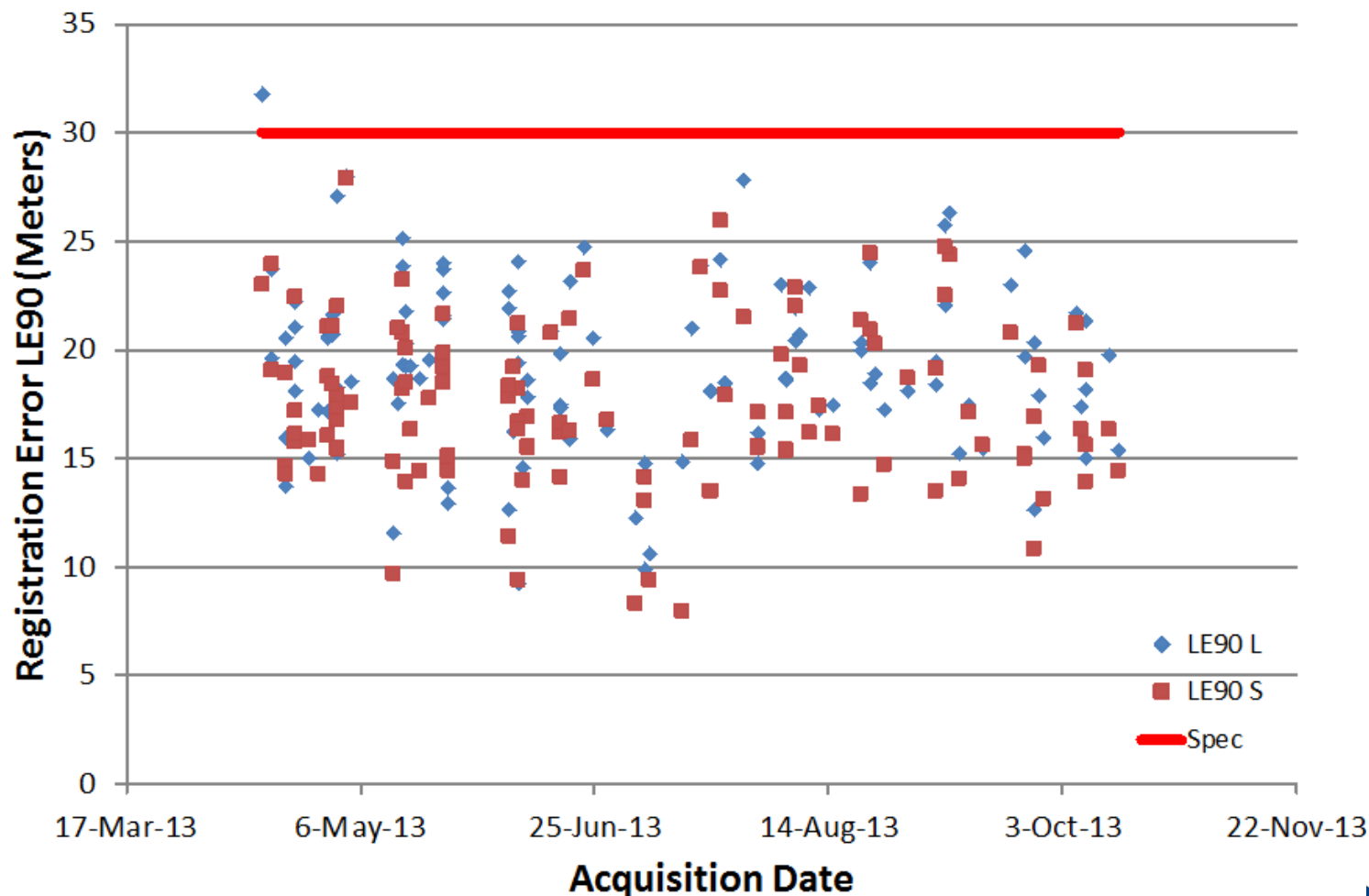
- Results from 139 TIRS band registration test scenes acquired from April 15, 2013 to October 22, 2013
- TIRS band registration accuracy
  - ❖ Line Direction: 10.5 meters LE90
  - ❖ Sample Direction: 8.7 meters LE90
  - ❖ Specification: 18.0 meters LE90

## ◆ TIRS to OLI band registration

- Results from 116 TIRS-to-OLI registration test scenes acquired from April 15, 2013 to October 15, 2013
- TIRS-to-OLI band registration accuracy (worst band pair)
  - ❖ Line Direction: 20.8 meters LE90
  - ❖ Sample Direction: 18.8 meters LE90
  - ❖ Specification: 30.0 meters LE90

# TIRS-to-OLI Registration vs. Date

- ◆ Only one scene tested was above the 30 m requirement threshold



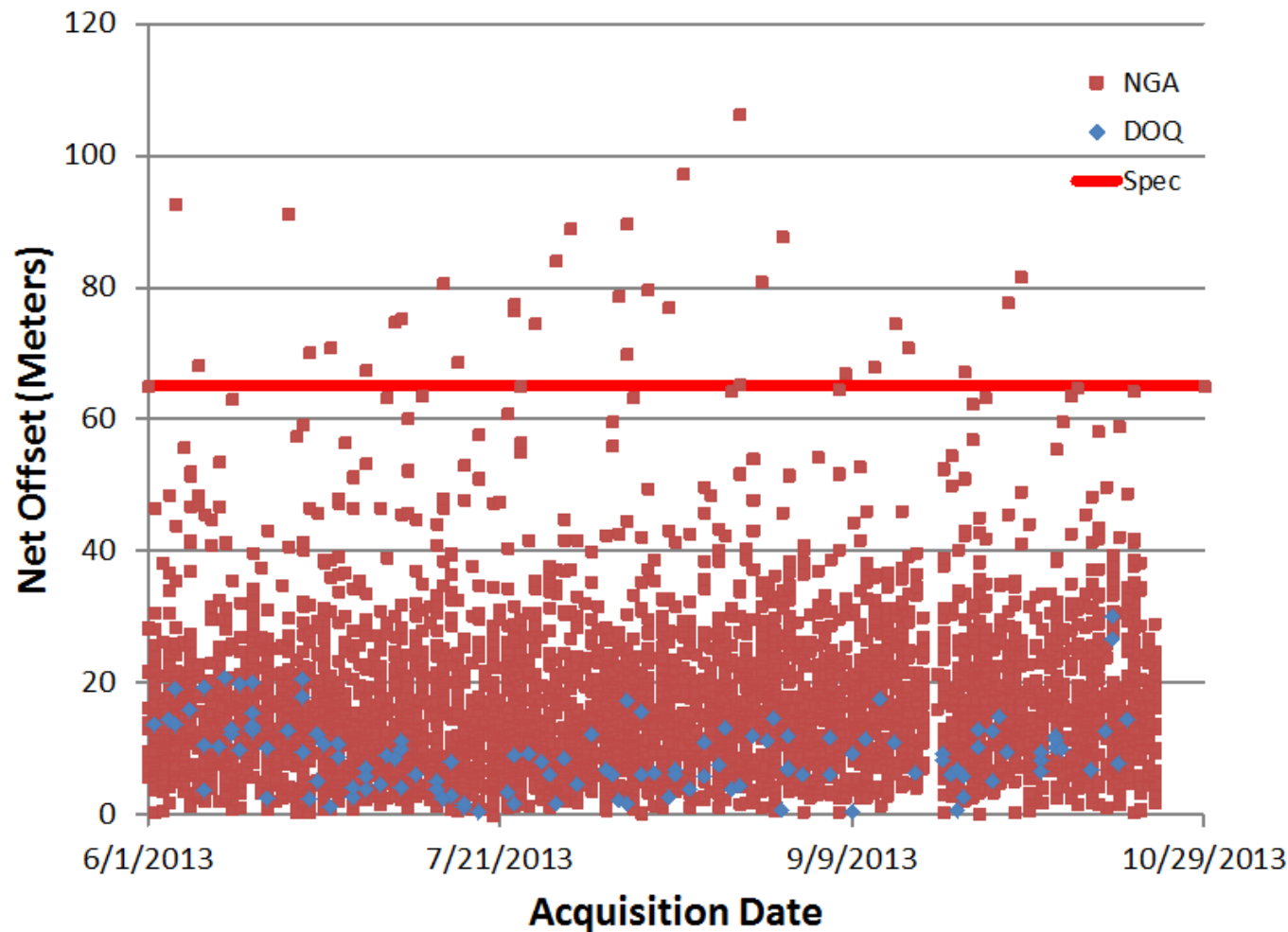
# Geodetic Accuracy

- ◆ **Geodetic accuracy is evaluated by measuring the offsets between OLI L1G (systematic) images and ground control points (GCPs)**
  - Geometric supersites (DOQ/GPS control) and Global Land Survey anchor sites (NGA control) were used for geodetic accuracy characterization
- ◆ **OLI Geodetic Accuracy based upon 4718 characterization scenes acquired from WRS orbit and after OLI-to-ACS alignment cal**
  - Absolute Accuracy: 37.0 meters CE90
  - Specification: 65.0 meters CE90
  - Relative Accuracy: 20.1 meters CE90
  - Specification: 25.0 meters CE90



# Geodetic Accuracy Test Scenes

- ◆ 32 scenes (of 4718) from 7 sites are off by more than the 65 m CE90 specification:



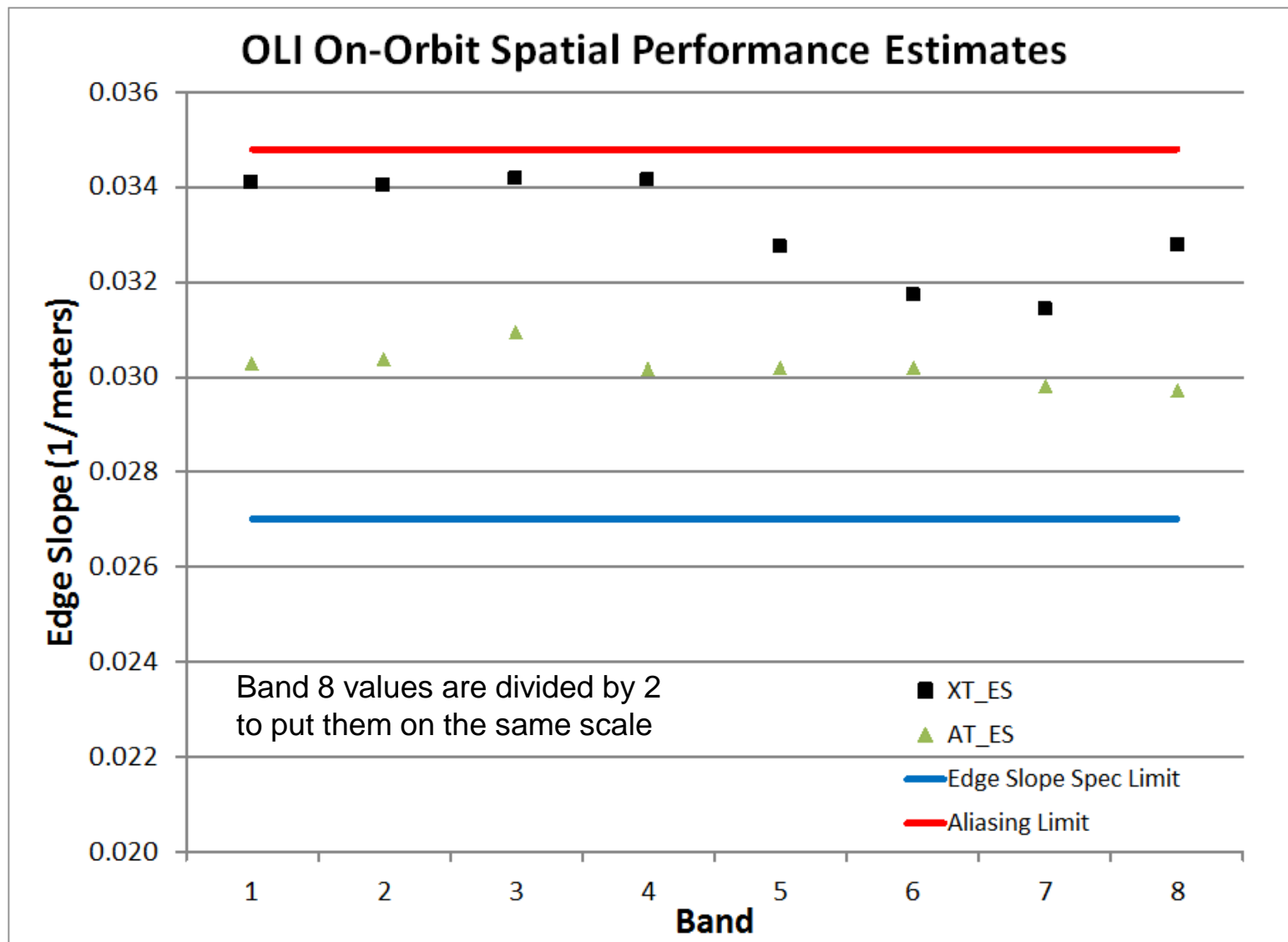
# Geometric Accuracy

- ◆ **Geometric (Level 1T product) accuracy is evaluated by measuring the accuracy of L1T products using independent validation GCPs**
  - Sites with sufficient GCPs have a subset withheld from the precision correction process to serve as independent validation points
    - ❖ Only NGA anchor sites are used for geometric accuracy characterization
- ◆ **OLI Geometric Accuracy based upon 6231 test site scenes:**
  - L1T Accuracy: 11.4 meters CE90
  - Specification: 12.0 meters CE90

# OLI Spatial Performance

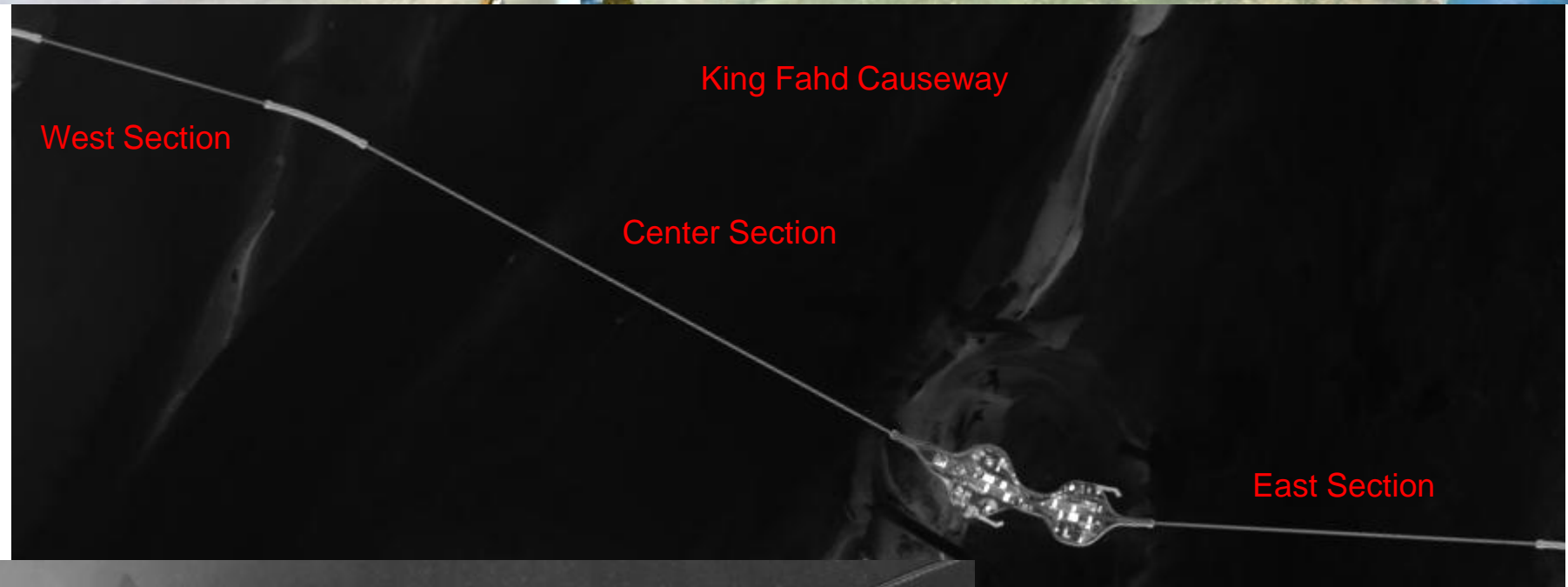
- ◆ **Bridge targets are used to characterize the OLI system transfer function on-orbit**
  - Level 1R image samples are interleaved to construct oversampled bridge profiles
  - Transfer function parameters are varied to make the modeled bridge profile best fit the image profile
  - Best fit model is used to generate spatial parameters
- ◆ **Analysis of 101 bridge targets in 47 scenes indicates that OLI is meeting spatial edge slope and half edge extent requirements**
  - All bands well above minimum edge slope requirement
  - Some bands are close to the upper limit set by the aliasing requirement
    - ❖ Both limits are shown on the following plot

# OLI Edge Slope By Band





# Bahrain and China Bridge Targets



Panchromatic Band Images

Single Span Bridges

# On-Orbit Jitter Assessment

## ◆ No evidence of on-orbit jitter was found

- Analysis of the ancillary attitude data showed that the 8 Hz solar array drive frequency is visible in the data, but no higher frequency disturbances were observed
- TIRS scene select mirror encoder telemetry shows no significant disturbances
- Dense tie point correlation to reference imagery showed no evidence of excessive time-correlated image disturbance
- OLI band-to-band registration accuracy performance is within specifications, suggesting no substantial degradation due to jitter
- OLI image quality is excellent and spatial performance is good

# L8 Performance Summary

## ◆ Landsat 8 on-orbit geometric performance is excellent and meets all requirements

Requirement	Measured Value	Required Value	Units	Margin
OLI Swath	190.2	>185	kilometers	2.8%
OLI MS Ground Sample Distance	29.934	<30	meters	0.2%
OLI Pan Ground Sample Distance	14.932	<15	meters	0.5%
OLI Band Registration Accuracy (all bands)	4.07	<4.5	meters (LE90)	9.6%
OLI Band Registration Accuracy (no cirrus)	3.37	<4.5	meters (LE90)	25.1%
Absolute Geodetic Accuracy	37.0	<65	meters (CE90)	43.1%
Relative Geodetic Accuracy	20.1	<25	meters (CE90)	19.6%
Geometric (L1T) Accuracy	11.4	<12	meters (CE90)	5.0%
OLI Edge Slope	0.03054	>0.027	1/meters	13.1%
TIRS Swath	186.2	>185	kilometers	0.6%
TIRS Ground Sample Distance	103.424	<120	meters	13.8%
TIRS Band Registration Accuracy	10.5	<18	meters (LE90)	41.7%
TIRS-to-OLI Registration Accuracy	20.8	<30	meters (LE90)	30.7%

# On-Orbit Calibration Updates

- ◆ **The initial on-orbit geometric calibration was performed during the commissioning period**
  - Measured OLI to spacecraft alignment
  - Measured OLI SCA-to-SCA alignment
  - Measured OLI band-to-band alignment
  - Measured TIRS-to-OLI alignment
  - Measured TIRS SCA-to-SCA alignment
  - Measured TIRS band-to-band alignment
- ◆ **Updated OLI-to-spacecraft alignment on July 1**
  - Small (10 microradian) adjustment (geodetic accuracy)
- ◆ **Spacecraft safe-hold event in September led to TIRS-to-OLI alignment change**
  - Calibration update issued effective 21SEP2013
  - Recent data suggest alignment may be drifting back

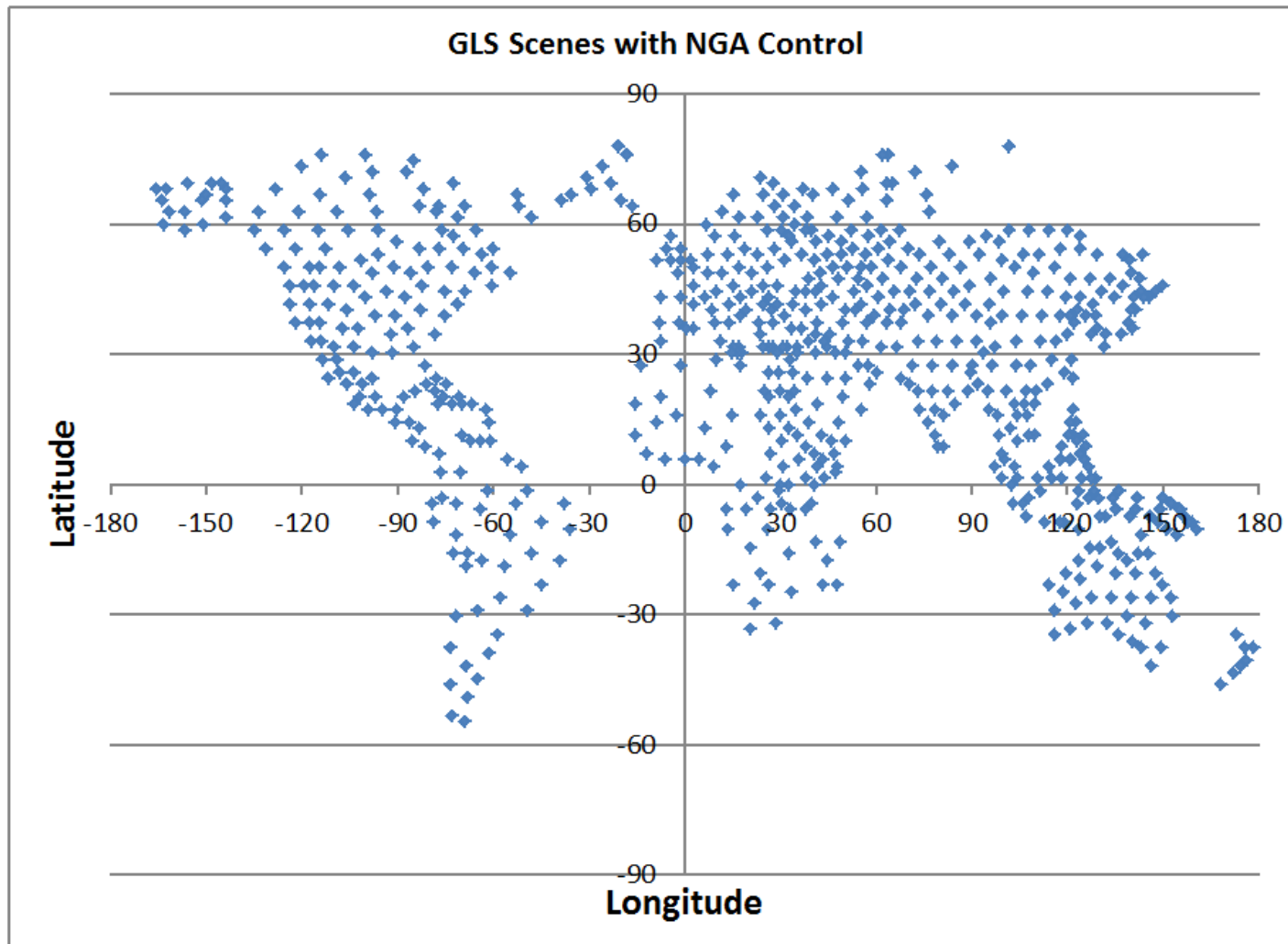


# Ground Control Accuracy Improvement

- ◆ **The global control point library used in Landsat L1T processing was derived from the GLS data set**
  - Ensures that new products are consistent with the existing archive (and each other)
- ◆ **L8 geodetic accuracy results indicate that, in some areas, the GLS control base is less accurate (in an absolute sense) than the OLI data right off the spacecraft**
  - This is manifested as repeatable large (tens of meters) offsets for particular WRS path/row locations
  - In these cases, L1GT (no control) products are closer to truth than L1T
- ◆ **The control library image chips are all L7 ETM+ (8-bit) and are getting older all the time**
  - We want to extract new OLI chips for the GCPs anyway
  - Would be a good time to repair areas that are geometrically problematic
- ◆ **The GLS was originally established by triangulating blocks of ETM+ imagery containing sparse control provided by NGA**
  - Scenes containing NGA control are referred to as “anchor” sites
  - Some areas (e.g., NE Asia, islands) had little or no NGA control
  - L7 L1GT scenes from “quiet gyro” period were used to control these areas

# NGA Anchor Site Distribution

- ◆ Note the gap north of 60N and east of 90E



# Three Types of Control Problems Identified

## 1. Scenes where bad control was extracted

- Three cases where the GCPs from a single WRS scene are inconsistent with the neighboring WRS scenes.
- This ground control can be replaced using the existing GLS data making them consistent with their neighbors.

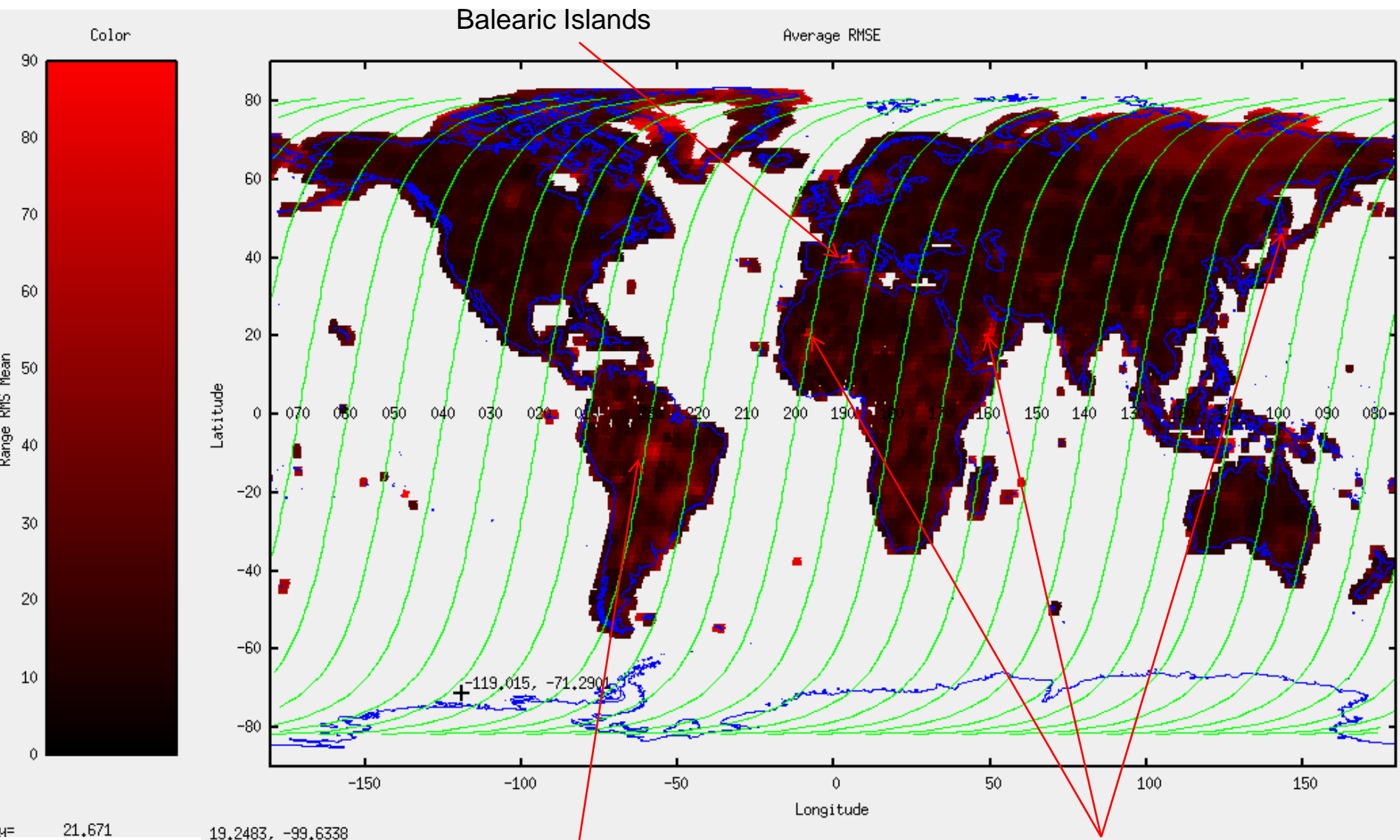
## 2. Areas where the GLS framework is inaccurate

- In a few areas, the GLS control has systematic biases of more than 100 meters.
- CPF precision correction parameters/constraints can prevent these from being registered to L1T.
- Have identified 15 areas with consistent offsets above 75 m, though there are others (mostly islands and NE Asia where there was no NGA control) with smaller offsets.

## 3. Scenes with problematic feature content.

- Some scenes with large offsets, such as 184/048, are problematic due to long term changes in the landscape (e.g., migration of dune patterns) rather than to bias errors in the circa 2000 GCPs.

# Distribution of Measured Control Bias



Area has Pre-Fit RMSE  
of around 80 meters

Hot spots for high pre-fit RMSE



# Current Status

- ◆ **Routinely generated L8 geodetic accuracy data are identifying regions where global GCP library contains biases**
  - New control has been generated for problem areas where the errors are isolated to a single scene (3 instances)
  - There are another 15 areas that have large (>75 meter) offsets due to lack of NGA control in the region (10 of these are islands)
- ◆ **Satellite block triangulation techniques show promise as a method for improving control accuracy in weak areas**
  - Balearic Islands test block successfully processed
  - Worldview data used to verify triangulation results
- ◆ **A plan and schedule for fixing and replacing the control in problematic areas is being developed**
  - New control point positions will be derived and inserted into the GCP library in WRS path/row units (i.e., entire scenes) with all control in a given area being replaced at the same time
  - Data acquired in these areas will be reprocessed and users will be notified
  - The control updates will also be propagated back to the heritage Landsat control database
  - New OLI GCP image chips will be extracted for the entire library

# Ongoing Work

- ◆ **Continue to routinely monitor Landsat 8 OLI/TIRS geometric performance**
  - Currently watching TIRS-to-OLI alignment as it stabilizes following the safe hold event
- ◆ **Developing augmented L1T product that will allow users to calculate per pixel solar illumination and sensor viewing angles**
  - More about this tomorrow
- ◆ **Developing plan for improving the accuracy of the Landsat ground control point database**
  - Will start with 15 high priority areas
  - Many problem areas are islands (that did not have NGA control) which are relatively easy to repair and replace without disrupting surrounding data